Original research

Intra-seasonal variation of injury patterns among German Bundesliga soccer players

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ABSTRACT

Objective: High fluctuations in injury-risk during the playing season in soccer have been reported. As seasons are structured in periods with homogenous loads and intensities, we investigated injury-risk over season periods, contrarily to previous studies adopting a month-based approach.
Design: Cohort study; Level of evidence, 2.
Methods: Incidence-rate ratios (IRRs) for match and training injuries were compared across six consecutive seasons of German Bundesliga, divided into six periods each: Pre-season (PS), winter-break (WB), quarter 1–4: (Q1–Q4).
Results: Significant variations in injury-risk were observed for match and training injuries. IRRs in matches was 1.30 (95% CI: 1.11–1.53) times higher in Q3 and 1.53 (95% CI: 1.31–1.78) higher in Q4 compared to Q1. For training injuries, IRR peaked in Q1 and Q3 followed by a marked decrease in each subsequent quarter. Compared to Q4, IRR was 1.62 (95% CI: 1.40–1.86) times higher during Q3 and 1.78 (95% CI: 1.53–2.07) times higher in Q1. IRR was significantly higher in the competitive season compared to pre-season across match (IRR: 2.00, 95% CI: 1.30–3.00) and training (IRR: 1.27, 95% CI: 1.11–1.43) injuries.
Conclusions: The increased match IRRs later during the season indicate that, in practice, coaches should consider putting even more emphasis on recovery in the last part of the season. Moreover, training injuries seem to indicate a carry-over effect. Further studies need to investigate how training during preparatory phases can be implemented in a way that prevents injuries during the competitive season.

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Practical implications

- The increased match incidence-rate evident throughout the season calls for the need to consider putting even more emphasis on recovery by the technical team towards the latter part of the season.
- Further studies need to confirm if indeed players train in the preparatory phases in ways that might predispose them to an increase injury-risk as observed by the carry-over effect.
- Actual values describing variations of injury-risk across season periods provided may allow the medical team insight necessary for enhancing injury management systems with the aim of alleviating injuries in contemporary professional soccer.

1. Introduction

At a professional level, the primary objective of a soccer club is success on the pitch. Success is linked to state-of-the-art facilities, coaching, management, talented, well-trained and above all, healthy players. High physiological, psychological, technical and tactical demands predispose players to a substantial injury risk. The risk of injury is estimated to be about 1000 times higher compared to industrial jobs regarded as high risk occupation[1]. As presented by Ekstrand, Dvorak, D'hooghe[2], considering professional players as employees, their current working condition in a team can equate to eight new injuries each week in a staff of 25 employees working full time (40 h per week). This hazard is especially alarming owing to the fact that this group contains over 60,000 professional soccer players worldwide.

Injury risk has been reported to vary considerably over the months of the season[3–5]. In some studies the difference between the highest (April) and the lowest (September) injury count in the competitive season was 150%[3,4]. Many reasons might account for these variations, e.g. accumulated fatigue as the season unfolds[6],

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reduced concentration resulting in decision making errors leading to match injuries[7], and critical play behavior such as duels and fouls increasing throughout the season[8].

This study suggests dividing the season into periods rather than into months as done until now when investigating the course of injuries over a season[3–5]. In line with the concept of periodization[9], professional soccer clubs organize the season into preparatory and competition periods[10]. Each of these periods has a unique profile in terms of work-recovery ratio, match/training ratio and friendly/competition match ratio, which is likely to directly influence injury characteristics. For example, the incidence rate of muscle strains was found to be highly correlated with players conditioning as indicated by an increase in average heart-rate in the Spanish La-Liga season period[5]. Training load data in the English Premier League indicated that average heart-rate values were significantly higher in the 3rd (end of first season halve) and 6th (last part of season) mesocycle of the season than in the first, with results indicating moderate effect size[11]. This example demonstrates how periodization can influence injury-risk.

The current study aims to describe and compare the pattern of match and training injury incidences among elite soccer players in the German Bundesliga during preparatory and competitive periods of the season. Specifically, we attempt to study the pattern of match and training incidence-rate (IR)'s across season periods and to investigate whether different injury types show different IR variations throughout season periods.

2. Method

This cohort study includes all male players with a first team contract in one of the 18 clubs in the 1st division of the German Bundesliga, over six competitive seasons (n = 1448). Injury and exposure data was recorded per player and was retrieved from a media-base register (www.transfermarkt.de), previously used in a study on injury-risk we conducted[12].

The data was acquired by an independent data scientist, who was not involved in analytics but developed a web-scrapper algorithm which extracted raw data from the register. Because data is based on the media, we performed some special measures, described in detail in our previous study[12], to verify the quality of the data. Injury diagnosis was translated from German to English and proofed by a medical doctor with native proficiency in both languages. A quality control phase was thereafter initiated by the first author (LL), a sports physiotherapist. In inconclusive cases, decision on injury data was made after advising with the second author (FE), also a registered physiotherapist. Following a quality control phase, data internal and external validity was assessed through reliability and cross-validation testing. Results indicated high agreement between the media-register and other two independent sources[12].

Players on trial or youth players without a professional contract were excluded. The study includes injury and exposure data from the 2008 to the 2014 season (July through May), as well as data from the preseason and winter-break period. Data from friendly matches, international duty (involving playing at the national team) and cup competitions together with official league matches were included in the analysis. Exclusion criteria accounted for exposure and injury data after the end point (official 34th Bundesliga match) of each respective season. This criterion slightly differs from our previous study[12].

After an off-season break, typically a Bundesliga season commences with a preparation phase. Then, the competition period starts with an interruption at around Christmas break for between 4 to 6 weeks, used first for recovery, and then for physical preparation. The second half of the competitive season takes place from January/February to May/June. Since the two competition sub-periods last around 4 months, it is appropriate to differentiate two halves in order to distinguish periods with more or less accumulated fatigue. This leads to a competition period structure of four quarters (Q1 to Q4). The 4 period lengths were calculated in number of weeks per season according to the following criteria:

- Preseason: from 1st July–1st official Bundesliga match
- Q1: 1st–7th Bundesliga matches
- Q2: 8th–17th Bundesliga matches
- WB: from the second day after the 17th match till the first day prior to the 18th Bundesliga match
- Q3: 18th–26th Bundesliga matches
- Q4: 27th–last (34th) Bundesliga matches

A time loss definition was adopted according to the consensus statement for injury definition in studies of soccer injuries[13]. Therefore, an injury was recorded if the player was unable to fully participate in soccer activity or match play due to any musculoskeletal disorders at least one day beyond the reported day of injury. The player was considered injured until his reported end day of injury, or alternatively until the first match played which he participated in. An injury was classified as match injury if reported on the same or the following day of a match in which the player was playing. A training injury was defined as an injury reported on any other day than a match injury occurred[12].

Exposure time was calculated separately for match and training injuries. For match injuries, player exposure was based on actual playing time in minutes. Due to lack of information regarding exposure time in minutes per player per training session, person-time was measured as player-week for training injuries. Descriptive results were presented in IRs with corresponding 95% confidence intervals (CI). IRs were calculated separately for match and training, and reported as injuries per 1000 match-hours for match injuries and injuries per 100 player-weeks for training injuries. Generalized linear mixed-effects models by maximum likelihood were fitted with each player injury count as a dependent variable, period of the season as an independent variable and time under risk (minutes played on weeks exposed) as an offset. In addition, a categorical variable injury type coded as either of the following: (1) muscle/tendon, (2) joint/ligament or (3) contusion/laceration was included in the model for the analysis of injury type through an interaction. An interaction term was added to test the hypothesis if the pattern of IRs throughout the season periods were significantly different across different injury types. Furthermore, the model included a random intercept, accounting for each player and each season. Assigning player id and season as a random intercept in a GLM mixed-effect model allows estimating coefficients of season periods accounting for potential individual and seasonal differences between players and between seasons[14]. These models were implemented for determining changes in incidence rate-ratio (IRR) throughout the different periods of the season. The first and second halve categories were created by aggregating Q1–Q2 and Q3–Q4. Also, the competitive season category was established by aggregating each quarter Q1–4 when comparing with PS and WB.

The calculation of type 2/3 analysis-of-variance was implemented using Wald chi-square tests in order to affirm for overall significance of regression models. A dispersion test was carried out to check for over-dispersion, hence selecting between a Poisson and negative binominal distribution when appropriate[15].

Alpha was deemed to be significant if p-value was below 0.05. Data preparation and analysis was performed entirely in R[16] using the AER[17], car[15] and lme4[18] packages.

3. Results

A total exposure of 114,637 player-weeks was recorded during the 6-year long study period. Exposure during matches accounted for 101,016 match-hours. A total of 3438 injuries was documented; 1397 (40.6%) match injuries and 2041 (59.4%) training injuries. The overall injury incidence during the study was 2.8 (95% CI: 2.7–2.9) injuries per 100 player-weeks. The incidence-rate for match injuries was 13.8 (95% CI: 13.1–14.6) per 1000 match-hours and for training injuries 1.8 (95% CI: 1.7–1.9) per 100 player-weeks.

Fig. 1 shows the distribution of injury incidence across the different periods of the seasons for match and training injuries. The difference in injury-risk between the two halves of the season were statistically significant for match ($X^2 = 50.2$, df = 1, $p < 0.001$) but not for training injuries. The risk of sustaining a match injury during the second part of the season was 1.4 (95% CI: 1.2–1.5, $p < 0.001$) times higher compared to the first half (reference category).

Dissecting the season into 4 quarters, the differences in injury-incidence over season periods were significant for both match and training injuries (for match: $X^2 = 56.3$, df = 5, $p < 0.001$; for training: $X^2 = 108.0$, df = 5, $p < 0.001$). Among match injuries, the risk seems to gradually increase throughout the quarters of the season. Comparing the quarter of lowest incidence-rate (Q1) as a reference category, the incidence rate ratio during Q3 and Q4 were both statistically significant, 1.3 times higher (95% CI: 1.1–1.5, $p < 0.01$) in Q3 and 1.5 (95% CI: 1.3–1.8, $p < 0.001$) in Q4 respectively. For training injuries, incidence-rate peaked in Q1 and Q3 followed by a marked decrease in each subsequent quarter. Taking the lowest incidence-rate (Q4) as a reference category, IRR was 1.6 (95% CI: 1.4–1.9, $p < 0.001$) times higher during Q3 and 1.8 (95% CI: 1.5–2.1, $p < 0.001$) times higher in Q1 (Table 1).

Significant differences in risk were observed between the pre-season, winter-break and the competitive season for both match and training injuries (match: $X^2 = 18.7$, df = 2, $p < 0.001$, training: $X^2 = 14.3$, df = 2, $p < 0.001$). For match injuries, IRR values showed a 2.0 (95% CI: 1.4–3.0, $p < 0.01$) fold increase of risk during the competitive season compared to the pre-season. In addition, the risk of sustaining an injury during the competitive part of the season was 3.2 (95% CI: 1.2–8.6, $p < 0.05$) times higher compared to the winter-break. No significant difference was indicated when comparing the risk players sustained between the preseason with the winter-break (p = 0.40).

For training injuries, the risk of sustaining an injury in the competitive season was 1.3 (95% CI: 1.1–1.4, $p < 0.001$) times higher compared to the pre-season. Almost the same holds for WB with risk relationship of 1.2 (95% CI: 1.0–1.5) times higher in the competitive season.

Fig. 2 shows the distribution of injury incidence across the different periods of the season in relation to injury types for match and training injuries. A significant interaction effect between season period and injury type was found among match injuries ($X^2 = 20.3$, df = 10, $p < 0.05$). In order to interpret the interaction term, stratified analysis could be performed to support the observations below. Differences in injury patterns were observed between muscle and contusions compared to sprain injuries. The risk of sustaining a muscle/contusion gradually increases throughout the season periods (excluding winter-break) while risk of sustaining a sprain decreases during the second part of each season half (Q2 and Q4) compared to the first half (Q1 and Q3).

Stratification based on injury type over season periods revealed the following risk differences for match injuries. Relative to the reference category (Q1), among muscle strain, IRR indicate no evident increase (1.1 (95% CI: 0.9–1.5, p = 0.373)) in Q2, but a 1.3 (95% CI: 1.1–1.7, $p < 0.05$) fold increase in risk in Q3 and 2.2 (95% CI: 1.7–2.9, $p < 0.001$) fold increase in risk in Q4. For muscle strains occurring in training, the lowest in-season injury risk was in Q2. Risk differences indicate a 1.5 (95% CI: 1.2–2.0, $p < 0.001$) fold increase in Q1, 1.4 (95% CI: 1.1–1.8, $p < 0.01$) fold increase in Q3, but no evident increase (1.1 (95% CI: 0.9–1.4, p = 0.38)) in Q4.

4. Discussion

The aim of the study was to explore the course of injuries over a professional Bundesliga soccer season. We introduced a period based data aggregation in contrast to a monthly unit of analysis used in previous studies[3–5]. Such aggregation reflects the notion of periodization more accurately, which conceptually differentiates the season into periods with unique profiles of characteristics relevant for injury risk, as mentioned initially. Months are not equivalent to periods, the latter ones are adopted to the time schedule of each individual season while the former do not reflect this organisation accurately. For example, in 2011/12 the season started on 5th August, while in the succeeding year it started on 27th August. In 2012, August belonged almost entirely to the preparation phase, but in 2011 almost entirely to Q1. In addition, in specific seasons January might be accounted for the most part either as a period of preparation/recovery–in 2008/9 matches started on 31th January–or as a mixed period of preparation/recovery and competition as was the case in 2009/10 when matches resumed on 15th January. By assigning each week of a season to a period, one is able to account for changes in interval duration occurring between seasons, which provides a more accurate insight into the distribution of work/recovery and competition/preparation rates throughout the season.

On the first glance, a methodology of assigning periods compared to months might be beneficial. However, its validity for the purpose of describing injury rates may be questionable. We have to acknowledge that collecting injuries per period is less fine-grained than using months as units of analysis, but we believe that this is compensated by the more uniform load profiles within a period compared to months. For example, the month of December in the Bundesliga typically contains match play as well as recovery which blurs the respective risk-factor profiles.

It is worth mentioning that, in terms of generalisability of results, of course the findings in the present study are specific to the Bundesliga, in the sense that there is specific programme to which periodization has to be fitted (each year). While there are some differences between competition calendars of different leagues (e.g. Premier League does not have a winter break), the principle of periodisation across seasons holds for each international league. The general assumption that periods have an impact on injury profiles is not challenged by the differences. However, this warrants additional investigations.

With regards to match injuries variation over season periods, with the exception of some cup matches or qualifying matches for international club tournaments (UEFA Champions and UEFA Europe league), reduced match IRs in the preseason and winter-break may be attributed to not only low number of matches and "friendlies" but also to the lower intensity of matches characterizing these periods. This pattern is in agreement with results from other studies[19].

Increase in match injury IRs during competitive season may, at least to some part, be explained by accumulation of fatigue. One study[20] aiming at explaining such increases found that accumulated stress and lack of recovery towards the end of a season was associated with high perceived physical complaints and injuries. Moreover, studies investigating the effect of congested fixtures found a fivefold increase in IRs in matches where players had four or less days of recovery compared to matches with six or more days of recovery[21]. This was said to be due to travelling and unfamiliar sleeping conditions. These factors among others are likely
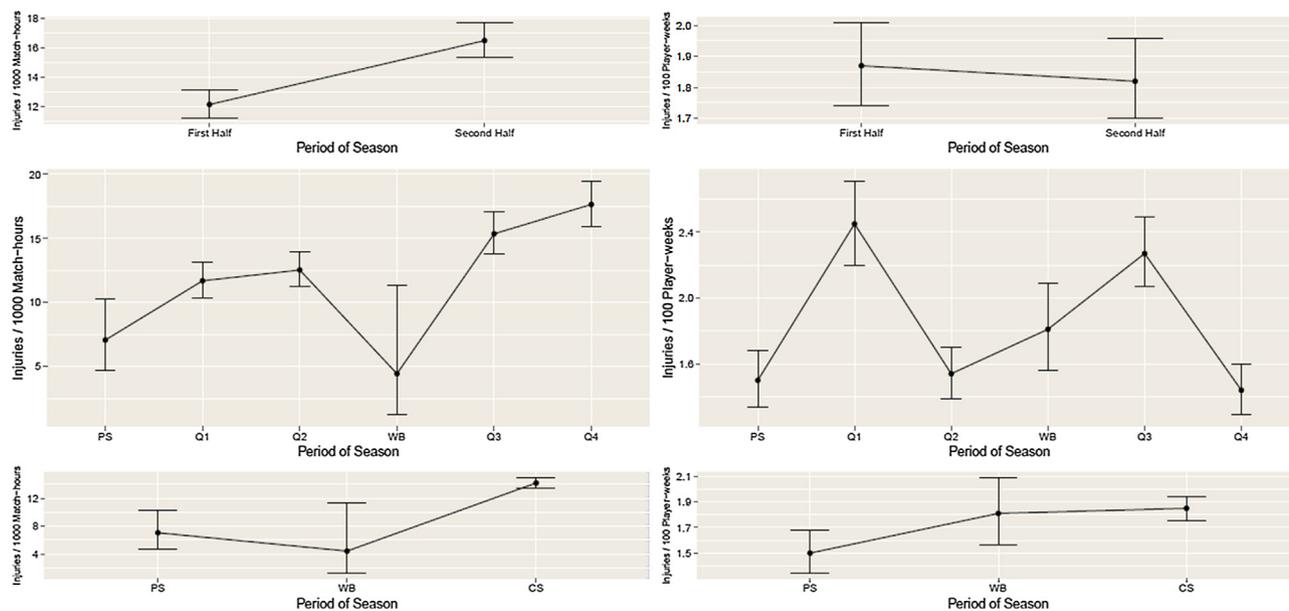
Fig. 1. Variation of injury incidence-rate across season periods for match (left panel) and training (right panel) injuries. PS = Pre-season, WB = Winter-break, CS = Competitive Season.

Table 1
Injury and exposure characteristics. *p < 0.05. **p < 0.01. ***p < 0.001.

	Preseason	Q1	Q2	Winter-break	Q3	Q4
Match						
Injuries	27	273	347	4	354	392
Exposure	3823.4	23343.9	27683.8	902.3	23040.6	22222.1
IRR (95% CI)	0.59	1.00	1.07	0.38	1.30	1.53
	(0.40–0.88)**	Reference	(0.91–1.26)	(0.14–1.02)	(1.11–1.53)**	(1.31–1.78)***
Injury type						
Muscle/tendon	8	83	112	1	109	173
Ligament/joint	12	64	67	2	78	44
Contusion/ laceration	2	23	33	1	57	78
Training						
Injuries	307	362	396	185	455	336
Exposure	20482.4	14790.9	25768.5	10216.2	20030.6	23348.1
IRR (95% CI)	1.03	1.78	1.10	1.29	1.62	1.00
	(0.88–1.20)	(1.54–2.07)***	(0.94–1.27)	(1.08–1.55)**	(1.40–1.87)***	Reference
Injury type						
Muscle/tendon	89	117	133	67	147	134
Ligament/joint	72	59	68	42	79	42
Contusion/ laceration	14	14	24	6	20	18

to cause deterioration in concentration, which may affect movement coordination and decision making, exposing players to an increase injury-risk throughout the later periods of the season. Quoting Ekstrand, Waldén, Hägglund[22]: "It may be that the major stress factor is not the 90 min of the match itself, but accumulated number of matches" (p. 495).

Another potential explanation for the increasing match injury IRs throughout the season may be accounted for by the increased number of decisive matches in the later part of the season, which, in turn, may lead to a more aggressive behaviour. Data from the Bundesliga indicate an increase in the number of fouls and duels throughout the season[8]. Foul play was previously reported to be the most important extrinsic risk factor, constituting between 12–61% of all injuries[23]. Furthermore, Junge, Dvorak, Rosch, Graf-Baumann, Chomiak, Peterson[24] found that 90% of all players were ready to commit a professional foul if required, depending on the importance of the game. As the season unfolds, the number of opportunities for securing placing on the league table decreases and therefore, each game becomes more important. Towards the end of a season, each remaining game becomes more important for

the final ranking which may provoke aggression and unnecessary risk taking behavior from players.

The previous explanation is confirmed when considering match IRs patterns in different injury types. Specifically soft tissue lesions such as contusions and lacerations increase towards the end of the season when matches become more decisive, including a higher number of fouls and duels that, in turn, leads to an increase in physical contact and soft tissue trauma.

In addition, the high muscle strain IRs during matches can be explained by the hypothesis of potential increase in accumulated fatigue throughout the season. In general, there seems to be a consensus across sports medical practitioners that fatigue plays an important factor in the pathogenesis of acute muscle strains[25,26]. Fatigue had been found to decrease the ability of muscles to absorb energy, specifically in the early stages of muscle stretching which could be closely related to a decrease in muscle contractile strength[25]. Most muscle strain injuries occur when muscles are subjected to eccentric load[26–28]. The muscle contracts eccentrically until the energy in the moving limb is absorbed, and concentric contraction can start[25]. Since fatigue was found to decrease the ability
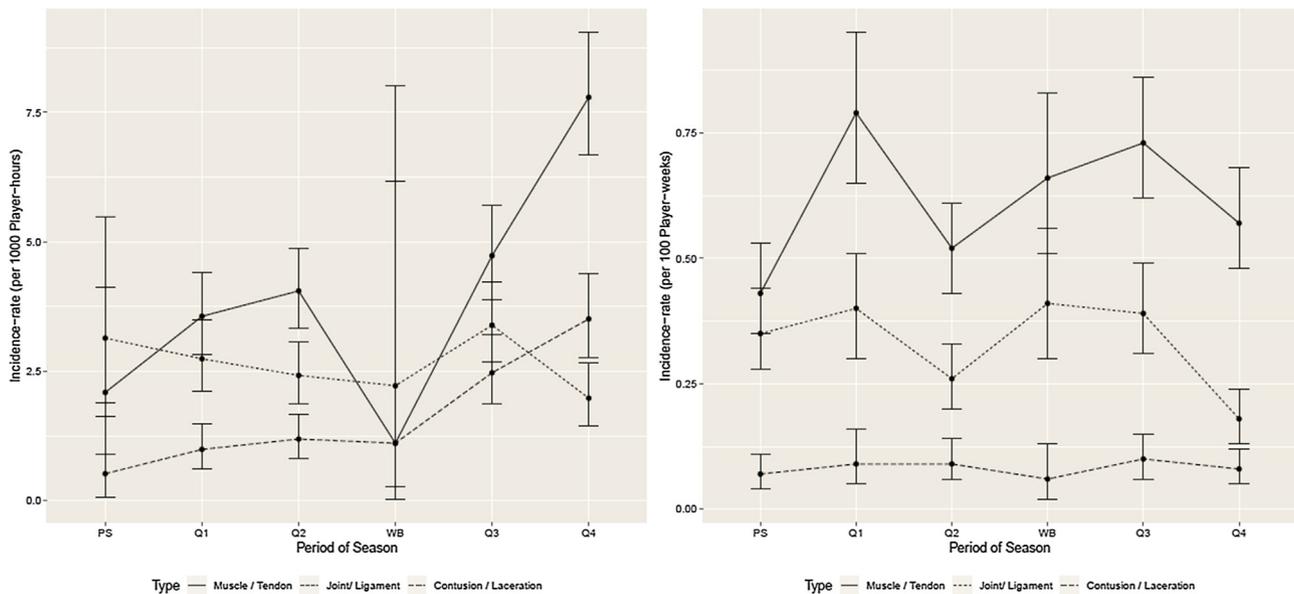
Fig. 2. Variation of incidence-rate across season periods as a function of injury typology for match (left panel) and training (right panel) injuries respectively.

of muscle to absorb energy, reduced muscular force development and contraction velocity, it is suggested to be an important factor in the aetiology and prevention of muscle injury.

With reference to training injuries variations over season periods, it is somewhat surprising that training injuries IRs peak in Q1 and Q3 whereas Match injuries peak in Q2 and Q4. This might be due to carry-over effects from the preparatory phases. In other words, the increased volume and intensity of training in the preparatory phases could potentially lead to an increase in training IRs in the first part of each competitive period, owing to a delayed effect.

A potential explanation for these carry-over effects can be due to the criteria used in the classification of an injury. Time-loss definitions adopted in this study comply with the consensus statement of soccer injuries[13]. However, as previously challenged[29], the precise onset of overuse injuries, most pronounced in training, is not captured if a time-loss definition is used to record injuries. It is likely that the pathological processes are often under way for some time before a player might notice the symptoms. Comparing time-loss injury registration and players interviews, Bahr[29] showed that players reported symptoms of pain while still taking part in training and competition, sometimes months before actual rehabilitation commenced. This shortcoming calls for the need of an alternative approach of injury reporting, which could be effective in identifying onset of overuse injuries.

Regarding the relative minima for training injuries in Q2 and Q4 one might assume that coaches might compensate for accumulated fatigue by reducing training volumes and intensity. This is meant to ensure optimal recovery for future decisive games.

Inspecting the type of injuries, we found the carry-over pattern (relative maxima in Q1 and Q3) even more pronounced for muscle and tendon injuries than in the overall training injuries pattern. This is in agreement with the hypothesized mechanism of the carry-over effect, because muscular strains and tendinopathies are primarily overuse injuries, attributed to gradual microtrauma[29]. Joint and ligament injuries IRs correspond to the general trend of muscle injuries. Contusions and lacerations do not show a very pronounced seasonal pattern. The increase of training IR evidenced in strains and sprains in the winter-break might be at least partly attributed to under-reporting of injuries from Q2 and even in Q1, due to variety of reasons, such as players fear of losing place in the team.

The recent decision of the British Premier League to introduce a winter-break from 2020 onwards is supported by the results of this study. The introduction of the winter-break is expected to have beneficial effects such as allowing for rest and recovery. The intended duration of two weeks, through seems to be too short for the purpose of implementing multicomponent preventive programs, typically requiring a minimum of between 6 to 8 weeks[30].

This study encountered a number of methodological limitations. As has been previously acknowledged[12], due to the nature of collecting data from the media, journalists or scouters may have been unaware of players' short absence from soccer participation, and therefore, injuries of minimal and minor severity are likely to be underreported, and hence expected, in part, to be missing from the register. Nevertheless, in terms of reporting bias, we expected injuries to be uniformly distributed throughout the season periods.

Unfortunately, the database does not distinguish between events occurring during international play (matches involving the national team), which makes estimating the incidence-rate affecting players in international duty difficult.

In addition, information on player team affiliation and training load were not provided. Training data is largely protected by club privacy which, given its absence, it is rather difficult to quantify load differences between clubs. It is expected that teams use different periodization strategies, according to their seasonal programs. For example, coaches might tailor their training programs differently if participating in the Champions League compared to other teams that need to consider only national competitions.

5. Conclusions

Recognising the significance of the variability in injury IR pattern across a season, from a methodological perspective, periods showed to be more promising units of analysis compared with months, where only fixed time intervals can be considered. In addition, we believe that the distinction between match and training injuries is important because findings show unique patterns each being governed by different effects, partly compensatory because training is reduced when match loads become too high.

Furthermore, even if coaches may deliberately control training load, based on the findings of increasing IR for match injuries as the

season unfolds, coaches should in practice consider putting even more emphasis on recovery in the last parts of the season.

Moreover, as evident from the carry-over effect, it seems that players train in the preparatory periods in a way that predisposes them to a high injury-risk in the competitive season, which is to be avoided. If these find ings are corroborated in further studies, there is a need to rethink training methods in the preparatory period of the season.

Finally the possibility that accumulated fatigue may lead to higher match IR already after the first half season in German Bundesliga, highlights the importance of having a winter-break. Seen in this light, the recent made decision of the British Premier League to introduce a winter-break is supported by our findings.

Acknowledgments

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